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Cost reducing agricultural research is rapidly shifting the economic advantages of food production away for the developed countries such as the U.S. toward the less developed countries located in the tropics. As a result, a state like Ohio which sells approximately one-fifth of all its agricultural production to foreign markets is facing substantial adjustments in its international food market. Increasingly, emphasis will need to be placed on making Ohio's food exports flexible, price-competitive, and high in quality. A number of traditional markets may soon be closed to Ohio's food exports.

Several years ago a cloud of doom hung over the prospects for food production in many parts of Asia. Famine, widespread malnutrition, unchecked population growth, and the need to import massive amounts of food were the main preoccupation of government officials. During the past three years, however, a number of Asian countries have experienced sharp increases in their production of wheat and rice. A "green revolution" has apparently begun. The increase in yields have been so sudden, so dramatic, that policy makers are now fretting about unstored surpluses, sagging prices, and where to export excess production. In large measure this drastic change in outlook for food has been caused by the introduction of new high yielding varieties of wheat and rice suitable for large

acreages in Asia.

Understandably, U. S. agricultural exports to Asia are being, and will continue to be importantly affected. The recent sag in international wheat prices and resulting price cutting on wheat export prices, stock build up of unmarketed wheat in the U. S., and the smallest U. S. wheat exports in over a decade during this past year are all directly related to these changes in Asia.

The Role of Wheat Research

The easing of the food crisis in Asia through introduction of new wheat and rice varieties is a clear demonstration of the high returns which can be realized from well directed agricultural research. In the case of wheat for example the high yielding varieties of semi-dwarf wheat which have recently spread like wildfire through Turkey, Pakistan, and India are the product of almost thirty years of concentrated effort. These varieties trace their origins back through the wheat breeding efforts started by the Rockefeller Foundation in Mexico during the early 1940's. In 1943 Mexico was importing 10 million bushels of wheat annually, and average wheat yields were about 11 bushels per acre. To increase these yields, Rockefeller began a research program aimed at creating better yielding rust resistant varieties of wheat for Mexico. A small, yet highly skilled team of scientists was brought in to begin the program, and young Mexicans were soon trained to handle many of the research steps. A large collection--tens of thousands--of different wheat varieties was soon collected and breeding work begun.

Dramatic results were achieved from this research by 1962-63 as Mexico increased wheat production by 3 and 1/2 times over the early 1940's, and was exporting about 4 million bushels of wheat. Yields were

up from the 11 bushels per acre in 1943 to 30-40 bushels in 1963.

Importantly, for what later happened in Asia, research with dwarf wheats was included in the Mexican program in the early 1950's. Researchers at Washington State University had developed several lines of dwarf wheat from imported Japanese varieties. The short stem characteristic was especially desirable since it was less likely to lodge with high rates of fertilizer application and irrigation. By 1961 sufficient research had been completed on these short stem varieties so that several rust resistant dwarfs were released in Mexico. Within four years these new high yielding varieties were planted on over 95 percent of the wheat area in Mexico.

It is not surprising that several food deficit countries in Asia were very interested in trying Mexico's "miracle wheat". In 1963 India began planting Mexican wheat, Pakistan started the next year, and Turkey initiated a large program in 1967. During the planting year 1968-1969, Turkey seeded 1.6 million acres, India 11 million acres and Pakistan 6.2 million acres of these semi-dwarf wheats. The almost 19 million acres planted in dwarf wheats in these three countries is equal to more than one-third of the U. S. wheat acreage. The new wheat varieties, large amounts of fertilizer, and improvements in other cultural practices resulted in additional wheat production in these three countries of 15.5 million tons during 1968-69. This additional production in only three countries is equal to about one-third of U. S. production in 1968, and also equal to three-quarters of all U. S. wheat exports in the same year. For further contrast, this additional production is equal to almost five times the size of the U. S. CCC holdings of wheat as of December 31, 1968. The rate of adaption has been simply astounding. It is doubtful

if the world has previously experienced any technological change in agriculture which has covered as many farms and acreage in so short a period of time. In the U. S., for example, it took 18 years for 80 percent of the corn acreage to be planted to hybrid varieties.

The Role of Rice Research

The rice research story is a briefer one. In 1962, the Rockefeller Foundation with assistance from the Ford Foundation, The Agency for International Development and the Philippines Government began a rice research center in the Philippines. Fortunately, a good deal of research on rice had been carried out by Asians, especially the Japanese and Taiwanese. The small group of skilled researchers assembled at the International Rice Research Institute, in fact, found themselves on the threshold of a major breakthrough.

Rice breeders at the Institute quickly began to put together several new rice varieties which had the following desirable characteristics: short stature, stiff-strawed, erect leaves, short growth duration, disease resistant, high yielding, resistant to insect damage, and seed dormancy. Less emphasis was placed on milling and eating quality. Within three years several new varieties, namely IR-8 and IR-5, were developed and ready for commercial use. In general, they included the desirable characteristics which the plant breeders had sought. Especially, the new varieties included the dwarf characteristics which allowed high levels of fertilizer application without lodging.

Again, the spread of the new varieties and their impact on production has been amazing. The Philippines, for example, had imported rice for over 70 years to the tune of 20 to 50 million dollars worth per

year up until 1968. Only three years after the high yielding varieties of rice became available, the Philippines became a rice exporter, and earned seven million dollars in 1968 from rice sales. In most cases the new varieties doubled production over traditional rice and in many cases yields were increased by three to four times. Because of the shorter growing period, double cropping became possible in irrigated areas. Within three years most of the better irrigated rice lands in the Philippines were planted to high yielding varieties. This is approximately one-fifth to one-quarter of all rice lands. Also, chemical fertilizer sales shot up by one-third in the 1965 to 1968 period.

Almost immediately India, Pakistan, and Viet Nam also began to experiment with the new "miracle rice" varieties. Again, within three years, by the 1968-69 planting season, over 11 million acres had been planted to new high yielding rice varieties in these four Asian countries. India had nine million acres, the Philippines 1.2 million, Pakistan 1.2 million and Viet Nam forty-four thousand acres. The additional yields from these plantings amounted to over five million tons of rice. In relative terms this amounted to two-thirds of the 7.5 million tons of rice which made up the total world exports of rice in 1967/1968. The U. S. is the leading exporter of rice, but our recent annual exports only amount to 40 percent of the increase in rice production expected in these four countries in the 1968/69 season.

Lessons to be drawn

In the space of five years (1964-69) the area planted to high yielding varieties of rice and wheat have zoomed in Turkey, Pakistan, India, Viet Nam, and the Philippines from a few acres in research plots to over 30 million acres. Over 20 million additional tons of rice and

wheat were available for consumers in these countries last year because of these new varieties. In value terms this increase in output in 1968/69 will be worth well over one billion dollars net to the countries involved. Interestingly enough, this amount is roughly equal to the economic assistance provided by the U. S. to these countries in 1968/69.

In addition, the rapid spread and adaption of these new cereal varieties among the so-called "traditional farmers" in less developed countries strongly suggests that they are much less resistant to change than many people have thought. If they find highly profitable technological changes with the proper mix of necessary inputs, most farmers in less developed countries will rapidly adopt the change.

The experience in Asia and Mexico with new cereal varieties also strongly suggests that concentrated research efforts on agricultural problems in less developed countries can pay off for the countries involved. As pointed out earlier, this very successful research on wheat and rice in Mexico and the Philippines was carried out by only two small groups of scientists. As a side light, most individual Departments in Colleges of Agriculture at U. S. Universities have more personnel working on agricultural research problems in the U. S. than were found in either of these two Research Centers. Since so little appropriate agricultural research has been done in tropical areas, dramatic results from research are much easier to arrive at than is true in the more prosperous countries.

If the less developed countries, with foreign assistance, begin to make significant investments in their agricultural research facilities, further major changes in the structure of the world's food marketing system will result. It is highly likely that a major portion of the

world's cereal market for example will disappear as tropical countries become self sufficient in wheat and rice. Careful research on oil crops and livestock in these countries could also sharply alter output. Cattle production in major parts of Africa, for example, could jump very rapidly if an effective way of controlling the tsetse fly is developed. In other cases, millions of acres of potentially productive tropical soils are currently not producing because little is known about the chemistry of these soils. Simply adding some limestone and a few cheap trace minerals may quickly bring these soils into crop production.

Ohio farmers will need to be very nimble to adjust to pending changes in world agricultural production.